RESEARCH DEPARTMENT

Stereophony: The effect of differences between the amplitude/frequency characteristics of left and right channels

RESEARCH REPORT No. L-049/4

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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STEREOPHONY: THE EFFECT OF DIFFERENCES BETWEEN THE AMPLITUDE/FREQUENCY CHARACTERISTICS OF LEFT AND RIGHT CHANNELS

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SUMMARY

In a stereophonic transmission system, differences between the amplitude/frequency characteristics of the left- and right-hand channels may result in displacement or dispersion of the sound images across the stage.

These effects have been subjectively assessed for such differences in channel characteristics as might be expected to occur in the S.B. system, and tentative suggestions made for the tolerances to be allowed on a pair of channels used for transmitting a stereophonic programme. The experiments were carried out as a contribution to the work of the E.B.U. in establishing performance limits for stereophonic transmission systems.

1. INTRODUCTION

The two channels necessary for the transmission of the left- and right-hand signals in stereophony should ideally have identical amplitude/frequency and phase/frequency characteristics. Failure to meet these requirements may lead to displacement of the reproduced sound images from their intended positions; where such displacement depends on frequency, the image of a complex sound source may be blurred through the dispersion of its individual components.

A previous report[1] in this series described an investigation into the effect, on the stereophonic presentation, of differences between the phase/frequency characteristics of left- and right-hand channels having amplitude/frequency characteristics identical within the working frequency band. The present report is concerned with the effect of differences between the amplitude/frequency characteristics of left- and right-hand channels containing only minimum phase-shift networks; in this case there can be no interchannel difference in phase/frequency characteristics save that which is unavoidably associated with the difference in amplitude/frequency characteristics. For the purpose of this report, the term 'interchannel amplitude differences' will be used for brevity to denote unintentional differences arising from lack of similarity between the channels, as distinct from intentional differences in amplitude between the original left- and right-hand signals to be transmitted.

In practice, the gains or losses in the two stereophonic channels are adjusted at the receiving point to be equal at mid-band, and it is therefore sufficient to consider only the divergence between the amplitude/frequency characteristics at higher and lower frequencies. In the tests to be described, the upper and lower ends of the audio-frequency range were investigated separately, using programme material appropriate to each case.

The widest divergencies between the characteristics of the left- and right-hand stereophonic channels are likely to occur in the lines from studio to transmitter, the more so because it may be desirable, as an insurance against total loss of programme through a line fault, to utilise lines following two different routes rather than two pairs in the same cable. The maximum degree of interchannel amplitude difference to be considered in the experiments was therefore based on the performance of the S.B. system. The upper and lower limits shown in Fig. 1, reproduced from a Designs Department report[2], embrace the frequency characteristics of 90% of the S.B. lines in use in 1948, and these were taken to represent the worst case which need be considered.

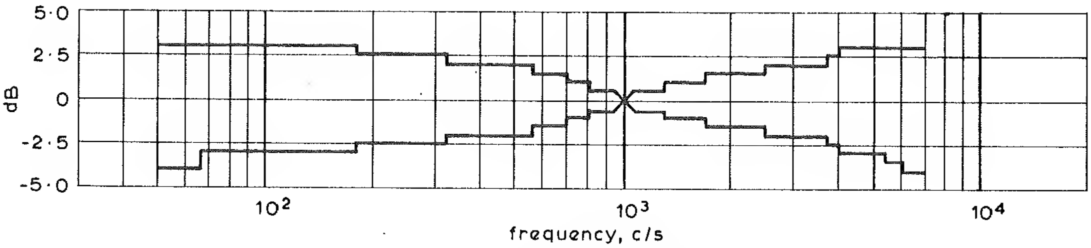


Fig. 1 - Amplitude/frequency response limits met by more than 90% of S.B. chains in 1948. (From data given in Designs Department Report No. 2.13 (51)).

2. GENERAL

Most of the tests were carried out in the same listening room and with the same equipment as in the experiments on the effect of interchannel crosstalk described in an earlier report in this series.[3] However, in accordance with more recent practice, all image displacements were specified as a proportion of the stage width rather than as an angle subtended at the observer's head. The numbered scale used to designate the position of the sound image was marked off in tenths of a stage width on either side of a centre zero. As in the previous investigation, some of the tests were repeated in a 'dead' room for which the reflexion coefficient of the walls, floor and ceiling was less than 10% at frequencies above 80 c/s.

Thirteen observers, all experienced in subjective judgments of this kind, took part in the experiments on interchannel amplitude differences at high frequencies and twelve in the corresponding experiments on differences at low frequencies.

The observer was situated equidistant from the two loudspeakers, thus avoiding any degradation in the image through differences in time of arrival of the sound from the two sides. In these circumstances, the image displacement produced by a small change in the amplitude ratio of the left- and right-hand signals is

greatest[4] when the two signals are nearly equal, i.e. when the image is near the centre of the stage. To simulate this condition in the experiment, the left- and right-hand channels were supplied from a common programme source, the difference in the amplitude/frequency characteristics being introduced by networks designed to increase the high or low frequency response of one channel while reducing the response of the other.

The limits shown in Fig. 1 embrace an infinite variety of amplitude/frequency characteristics, and for the present purpose it was necessary to make an arbitrary selection. Fig. 2 shows diagrammatically the form of characteristic, produced by

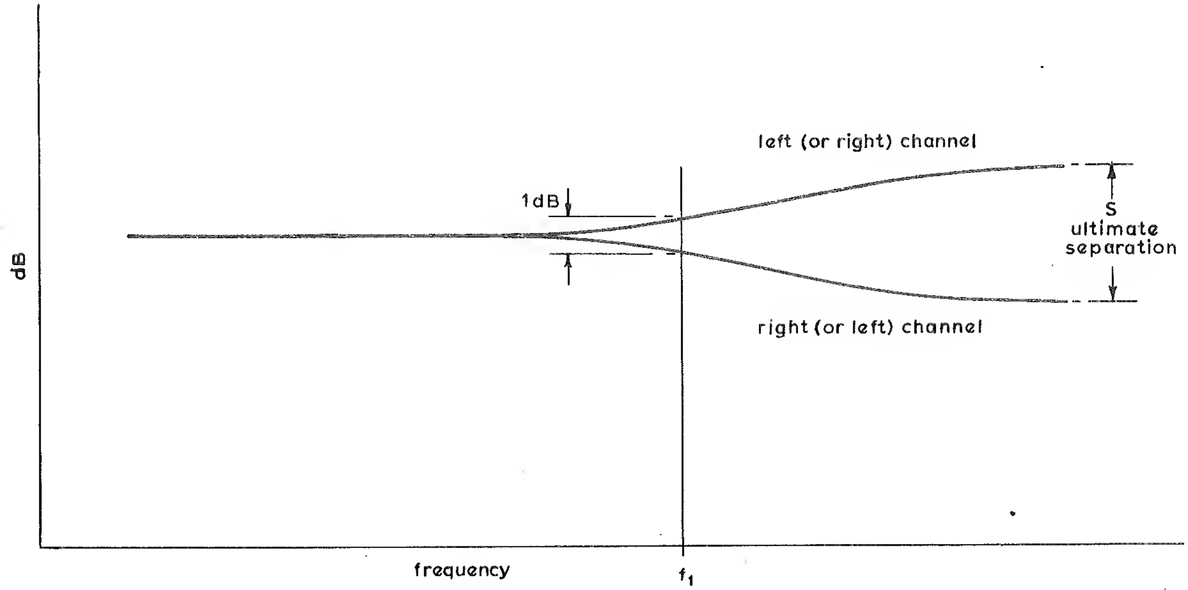


Fig. 2 - Method of specifying degree of interchannel amplitude difference at high frequencies

resistance-capacitance networks, chosen for the experiments on interchannel amplitude differences increasing at high frequencies. In one series of experiments, all the pairs of curves had the same ultimate separation S, the degree of impairment of the transmission being varied by altering the circuit capacitances, thus displacing the characteristics along the frequency scale without changing the form of the curves; for reference purposes, each condition was arbitrarily designated by the frequency f_1 at which the characteristics of the left- and right-hand channels diverged by 1 dB. In a second series, the degree of impairment was controlled by varying the circuit resistances, thus altering S; the value of the latter quantity was then used for reference. In both cases, the networks producing the desired amplitude/frequency characteristics were adjusted in steps by means of ganged rotary switches so arranged that an increase in response of one channel at any frequency was accompanied by a substantially equal decrease (on a dB scale) in the response of the other.

In the case of interchannel amplitude differences increasing at low frequencies, the characteristics of the two channels took the form shown in Fig. 3, which is a mirror image of Fig. 2; from the results of a pilot experiment, however,

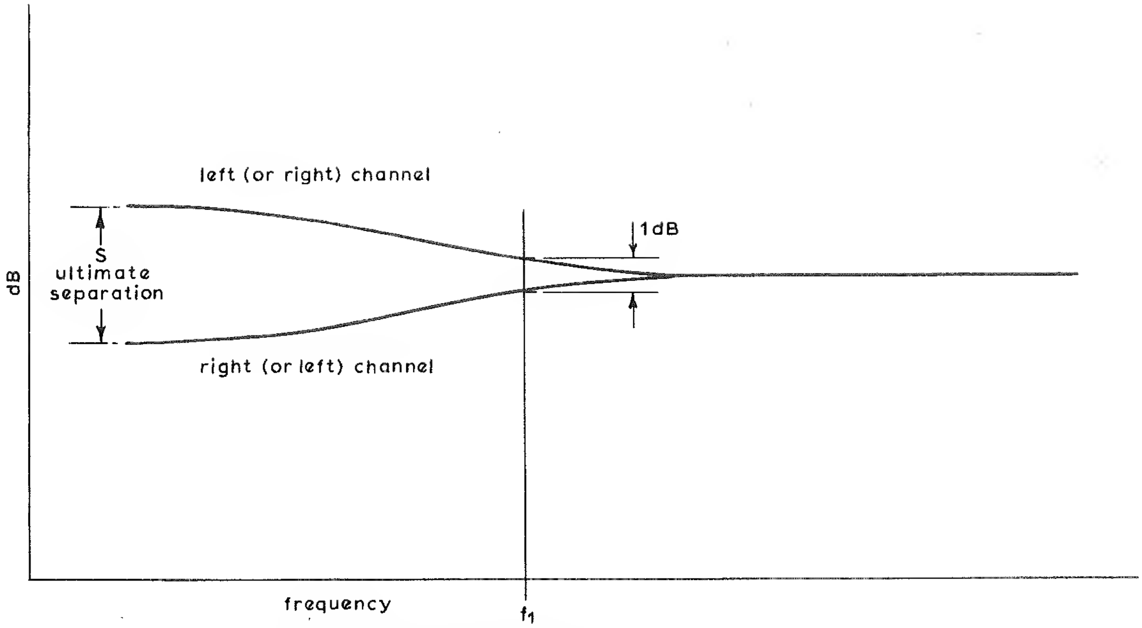


Fig. 3 - Method of specifying degree of interchannel amplitude difference at low frequencies

it was considered unnecessary to carry out a second set of tests with S as the independent variable and the investigation was therefore confined to the effect of varying f_1.

No attempt was made to phase-compensate the circuits used to vary the amplitude/frequency characteristics of the two channels, any interchannel phase differences thereby introduced being accepted as a natural attribute of the system under investigation. In the event, these phase differences were found in the most extreme conditions to be less than 25° and could not therefore[1] have contributed appreciably to the subjective effect.

At the commencement of each group of tests, the rotary switch controlling the difference between the amplitude/frequency characteristics of the two channels was set at one end of its travel; in this condition identical signals were applied to the left- and right-hand channels, and the resulting image will be described for convenience as 'unimpaired'. The observer was asked to adjust a trimming attenuator controlling the relative levels of sound from the two loudspeakers until he judged the image to be central. He was then asked to operate the rotary switch controlling the interchannel difference in amplitude/frequency characteristic and to find (a) the first position for which a displacement of the image became perceptible, and (b) the setting for which the edge of the image coincided with some designated position on the numbered scale extending across the stage. Equal numbers of tests were carried out with the image displacement to the left and to the right; the various experimental conditions were presented in random order to avoid any recognizable sequence which might influence the observer's judgment.

Even when the left- and right-hand channels have identical amplitude/frequency characteristics, the resulting unimpaired image possesses a finite width

which is a function, partly of any residual asymmetry in the sound reproducing system, and partly of the listener's own resolving powers. In a supplementary experiment, carried out with the same programme material and the same bandwidth restrictions as in the main experiment, each observer was asked to estimate the width of a central unimpaired image.

3. INTERCHANNEL AMPLITUDE DIFFERENCES INCREASING AT HIGH FREQUENCIES

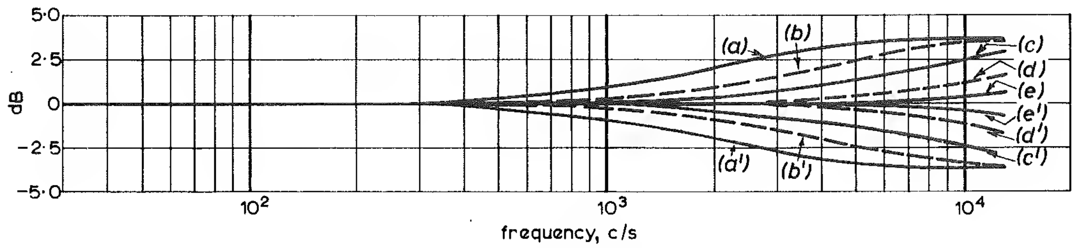
3.1. Experimental Details

The programme material used for these tests was a recorded excerpt of Latin American music, repeated as many times as was necessary for the observer to reach a decision.

The susceptibility of a stereophonic presentation to changes in the relationship between the left- and right-hand signals at high frequencies is known from earlier experiments[4] to be little affected by a reduction in the normal amount of reverberation. It was therefore considered unnecessary to repeat any of the tests in the dead room.

As in previous experiments in this series, an attempt was made to assess the part played by components in the upper part of the audio-frequency range. To this end, some of the tests were carried out with the bandwidth of the system limited to 10 kc/s or 6·8 kc/s by low-pass filters; in the absence of the filters, the upper frequency limit was set at 13 kc/s by the characteristics of the loudspeakers employed.

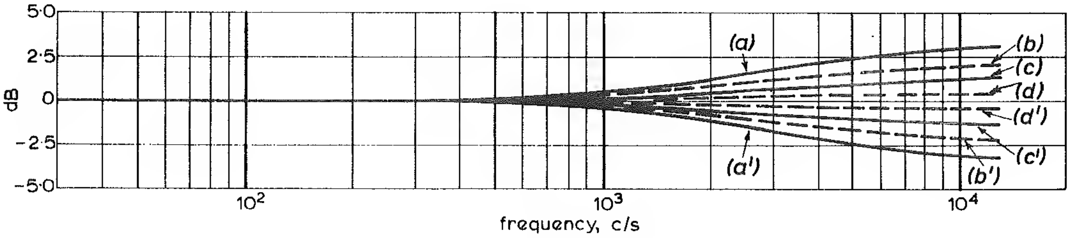
The amplitude/frequency characteristics of the left- and right-hand channels obtained by varying f_1 are indicated in Fig. 4; the observer's control switch



LEFT (OR RIGHT) CHANNEL	RIGHT (OR LEFT) CHANNEL	f_1 kc/s
a	*a'*	0·7
b	*b'*	1·4
c	*c'*	2·8
d	*d'*	5·6
e	*e'*	11·0

Fig. 4 - Amplitude/frequency response curves of networks used to introduce interchannel amplitude differences at high frequencies. (Alternate steps shown). f_1 *variable*

operated in eleven steps, but for clarity the characteristics for alternate steps only are given in the figure. Fig. 5 shows corresponding pairs of characteristics obtained by varying S; in this case, the characteristics are given for every third step. The pairs of characteristics in Fig. 4 were obtained by altering the reactances in the circuit, the ultimate separation S remaining constant at 7·5 dB; in Fig. 5, the reactances were kept constant at such values that with S = 6 dB, f_1 = 1 kc/s.



LEFT (OR RIGHT) CHANNEL	RIGHT (OR LEFT) CHANNEL	ULTIMATE SEPARATION S dB
a	*a'*	6
b	*b'*	4·2
c	*c'*	2·4
d	*d'*	0·6

Fig. 5 - Amplitude/frequency response curves of networks used to introduce interchannel amplitude differences at high frequencies. (Every third step shown). S *variable*

3.2. Results

Figs. 6(a), 6(b) and 6(c) show the results obtained with the upper frequency range restricted to 13 kc/s, 10 kc/s and 6·8 kc/s respectively, when the interchannel amplitude difference was varied, as shown in Fig. 4, by altering f_1; values of f_1 are plotted as abscissae to a logarithmic frequency scale so arranged that the degree of impairment of the system increases from left to right; the ordinates are plotted to a Gaussian probability scale. Curve (i) in each case shows the percentage of observations in which there was no perceptible image displacement; curve (ii) shows the percentage of observations in which the edge of the image was less than 0·1 of the stage width from the centre and curve (iii), the corresponding data for 0·2 of the stage width from the centre.

In most of the experiments, the points fall nearly on a straight line* indicating a Gaussian distribution. However, in these and similar figures given later, the lines representing different degrees of image impairment are in some cases not parallel and would therefore intersect if extrapolated; evidently the Gaussian distribution holds only over a limited range. The difference in slope between the lines, which, whenever it is statistically significant, indicates a decrease in standard deviation with decreasing image impairment, may be due partly to the finite width of the image.

Table 1 is derived from Figs. 6(a), 6(b) and 6(c). It shows the values of f_1 for which, in 50% of the observations, the subjective impairment of the image

* The line of best fit was arrived at in each case by the method described in Research Report A-037.

TABLE 1

Tests in Listening Room

SUBJECTIVE IMPAIRMENT OF NOMINALLY CENTRAL IMAGE IN 50% OF OBSERVATIONS	FREQUENCY RANGE RESTRICTED TO 13 kc/s		FREQUENCY RANGE RESTRICTED TO 10 kc/s		FREQUENCY RANGE RESTRICTED TO 6·8 kc/s	
	f_1 kc/s	S.E. (octave)	f_1 kc/s	S.E. (octave)	f_1 kc/s	S.E. (octave)
Imperceptible	10·5	0·15	9·3	0·15	5·4	0·1
Edge of image off-centre by less than 0·1 stage width	5·1	0·3	4·3	0·25	2·9	0·2
Edge of image off-centre by less than 0·2 stage width	1·7	0·25	1·6	0·25	1·2	0·25

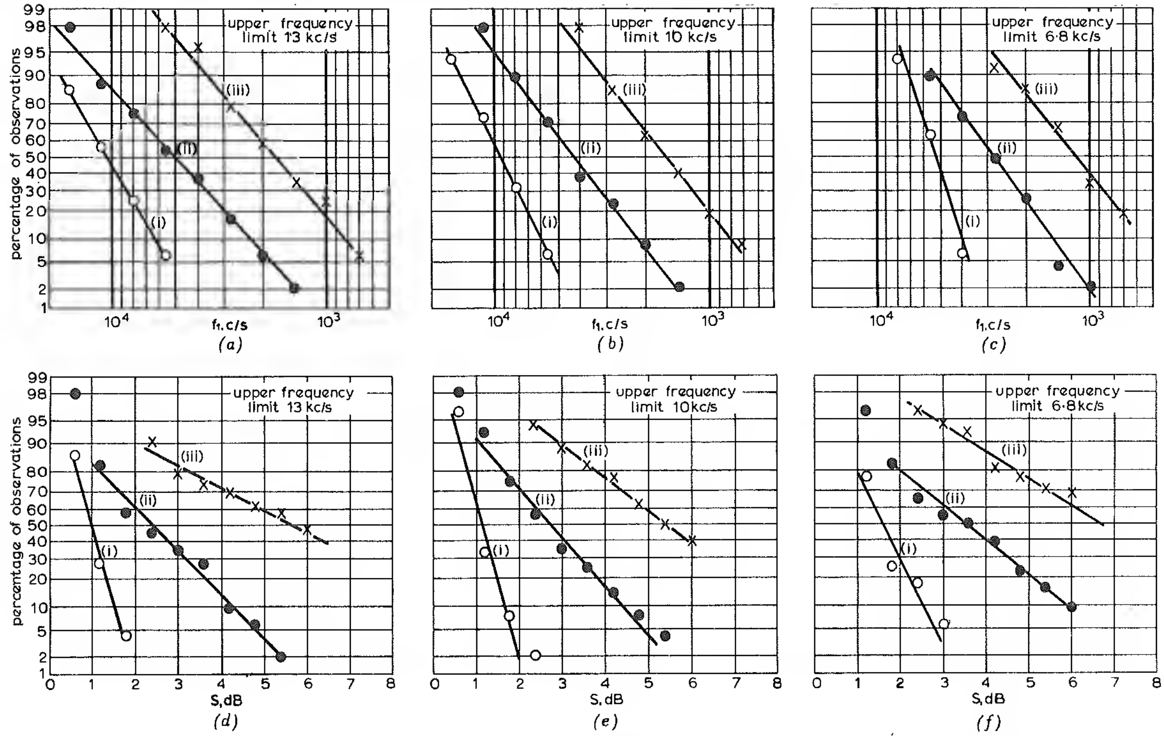


Fig. 6 - Subjective effect of difference between amplitude/frequency characteristics of left and right channels at high frequencies. Divergence of channels expressed in (a), (b) and (c) in terms of f_1, *in (d), (e) and (f) in terms of* S

Numbering of curves:-

(i) Percentage of observations in which there was no perceptible image displacement
(ii) Percentage of observations in which the edge of the image was less than 0·1 stage width from the centre
(iii) Percentage of observations in which the edge of the image was less than 0·2 stage width from the centre

caused by the interchannel amplitude difference can be classified as 'imperceptible', 'edge of image off-centre by less than 0·1 of stage width' and 'edge of image off-centre by less than 0·2 of stage width' respectively. The standard error of the mean (S.E.) is given in each case to the nearest 0·05 octave.

Figs. 6(d), 6(e) and 6(f) show the results obtained with the upper frequency range restricted to 13 kc/s, 10 kc/s and 6·8 kc/s respectively when the interchannel amplitude difference was varied, as shown in Fig. 5, by altering S. Apart from the change in the independent variable, the remarks already made with regard to Figs. 6(a), 6(b) and 6(c) apply here also. However, since there can be no impairment of the image when the interchannel amplitude difference is zero, there is an inevitable departure from Gaussian distribution as the curves approach S = 0.

Table 2, derived from Figs. 6(d), 6(e) and 6(f), shows the values of S, in dB, for which, in 50% of the observations, the effect of the interchannel amplitude difference can be classified as 'imperceptible', 'edge of image off-centre by less than 0·1 of stage width' and 'edge of image off-centre by less than 0·2 of stage width' respectively. The standard error of the mean is given in each case to the nearest 0·1 dB.

TABLE 2

Tests in Listening Room

SUBJECTIVE IMPAIRMENT OF NOMINALLY CENTRAL IMAGE IN 50% OF OBSERVATIONS	FREQUENCY RANGE RESTRICTED TO 13 kc/s		FREQUENCY RANGE RESTRICTED TO 10 kc/s		FREQUENCY RANGE RESTRICTED TO 6·8 kc/s	
	S dB	S.E. dB	S dB	S.E. dB	S dB	S.E. dB
Imperceptible	1	0·1	1·2	0·1	1·6	0·2
Edge of image off-centre by less than 0·1 stage width	2·4	0·4	2·7	0·4	3·5	0·6
Edge of image off-centre by less than 0·2 stage width	5·6	0·8	5·4	0·6	6·7	0·7

As already stated in Section 2, a supplementary experiment was carried out to find the width of a central image produced with identical left- and right-hand channels. For the Latin American music referred to above, the mean image width was found in this experiment to be 0·1 of the stage width (S.E. 0·01) with no significant difference between the results for the three bandwidths. This means that the unimpaired image was regarded by the observers as extending, on average, 0·05 of the stage width on either side of the centre. It follows that if the image is spread towards either side as a result of some system impairment and extends, for example, to 0·2 on the numbered scale, the edge of the image must have been displaced by only 0·15.

So far, the impairment in the stereophonic transmission system has for convenience been expressed in terms of the arbitrary quantities f_1 and S. It is now necessary to reverse the process and to consider what differences between the amplitude/frequency characteristics of the left- and right-hand channels are associated with a particular subjective grading. The result is shown in Figs. 7, 8 and 9, which are derived from Fig. 6 by interpolation. Fig. 7 shows the amplitude/frequency characteristics of the two channels for which the displacement of the image would in 50% of the tests be imperceptible. The data is given for the three bandwidths; the full line and dashed curves relate respectively to the results obtained by varying f_1 and S. Fig. 8 shows the amplitude/frequency characteristics of the two channels for which, in 50% of the observations, the edge of the image would be off-centre by less than 0·1 of the stage width, and Fig. 9 the corresponding data for 0·2 of the stage width.

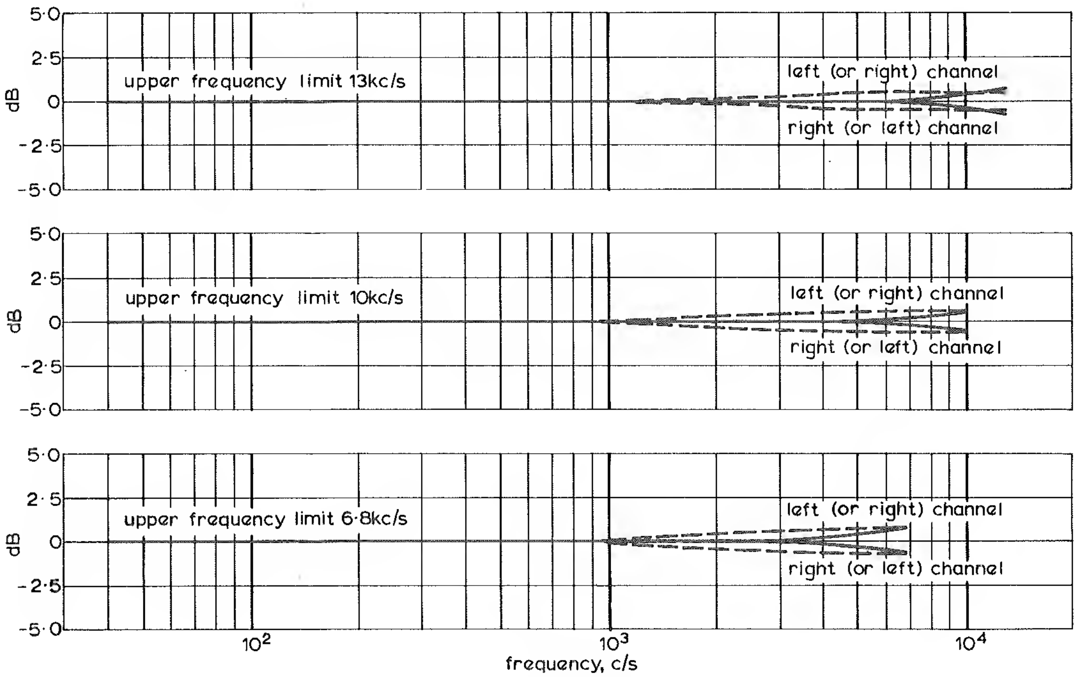


Fig. 7 - Amplitude/frequency characteristics of left and right channels at high frequencies for which there was no perceptible image displacement in 50% of observations

——— f_1 variable – – – S variable

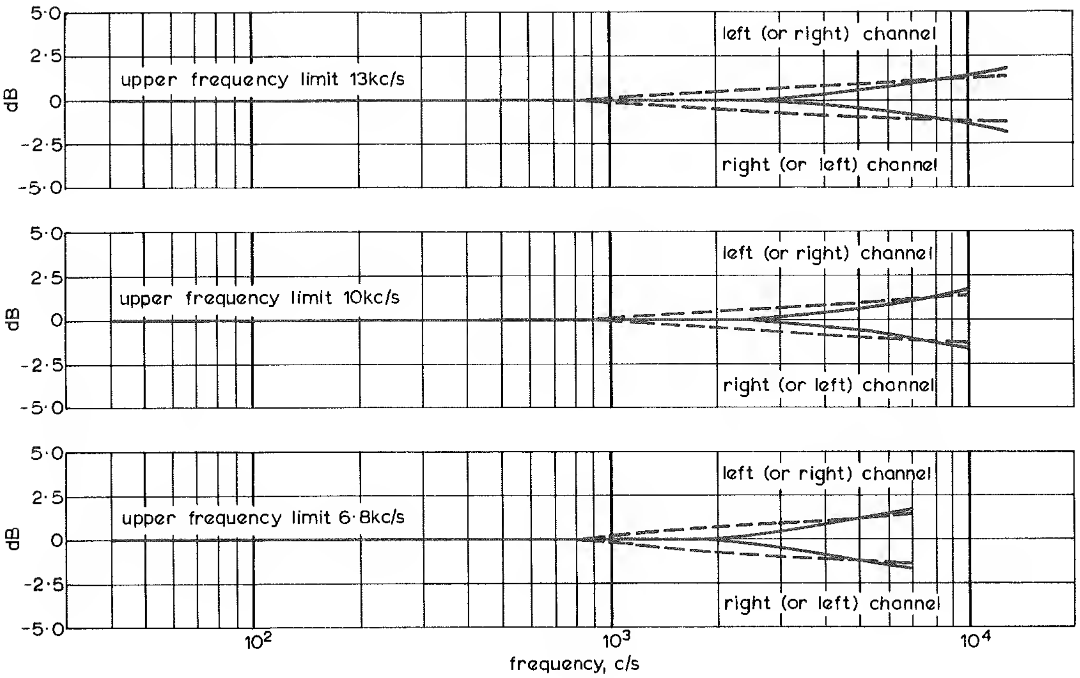


Fig. 8 - Amplitude/frequency characteristics of left and right channels at high frequencies for which the edge of the image was less than 0·1 stage width from centre in 50% of observations

——— f_1 variable ---- S variable

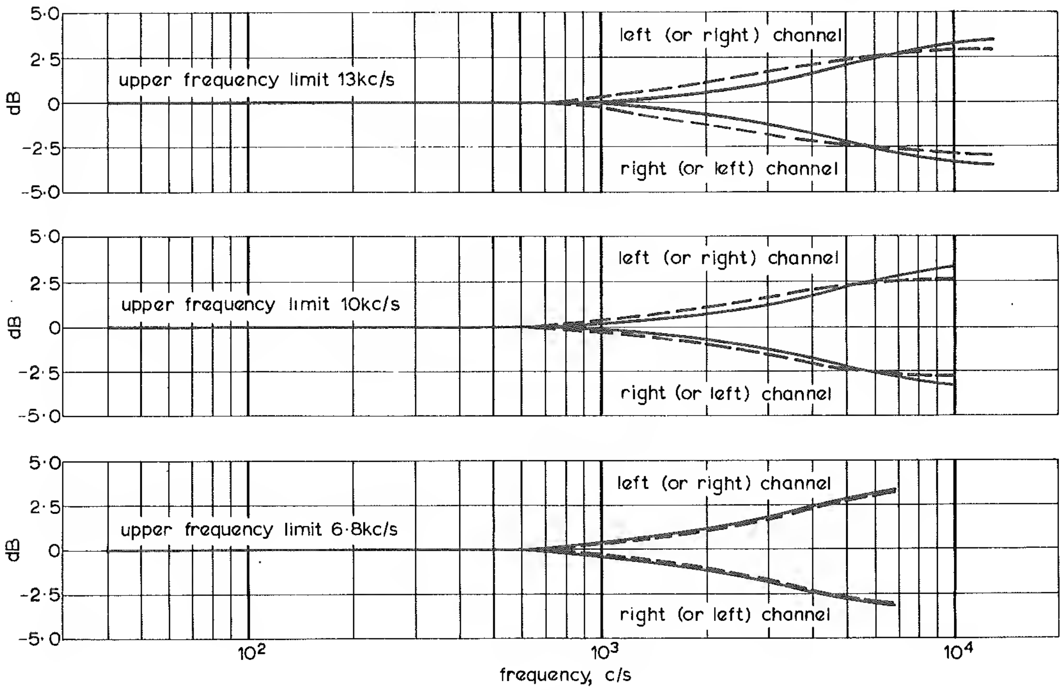


Fig. 9 - Amplitude/frequency characteristics of left and right channels at high frequencies for which the edge of the image was less than 0·2 stage width from centre in 50% of observations

——— f_1 variable ---- S variable

It will be seen that in Figs. 7, 8 and 9, each curve relating to variation in S intersects the corresponding curve relating to variation in f_1; it seems likely that the subjective assessment in each case was influenced largely by components having frequencies in the region of intersection.

It will also be noticed that for each subjective grading, the degree of divergence between the amplitude/frequency characteristics of the left- and right-hand channels at the upper end of the band is nearly independent of the bandwidth.

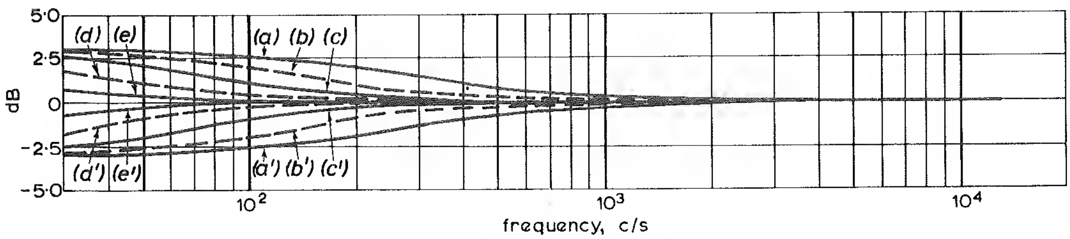
4. INTERCHANNEL AMPLITUDE DIFFERENCES INCREASING AT LOW FREQUENCIES

4.1. Experimental Details

The programme material consisted of excerpts from recorded solos on organ, bass drum and double bass played pizzicato; the test passages were repeated until the observer had come to a decision.

From previous experience[4] it was thought possible that the results of this part of the experiment might be significantly affected by a reduction in the amount of reverberation in the listening area. Tests were therefore carried out both in the listening room and in the dead room.

As long as the interchannel amplitude differences below 1 kc/s did not exceed the limits given in Fig. 1, the maximum impairment of the stereophonic presentation was not large enough to justify closer analysis by the introduction of filters to restrict the frequency band; tests were therefore made only with the full frequency range, limited at its lower end to approximately 40 c/s by the nature of the programme material and the characteristics of the loudspeakers. For the same reason it was thought sufficient to control the difference between the amplitude/frequency characteristics of the left- and right-hand channels by varying the frequency f_1 at which the curves diverge by 1 dB, the value of S being held constant at 6 dB. Fig. 10 shows the form of characteristic obtained by this means; as in the corresponding curves in Fig. 4, eleven different pairs of characteristics could be produced, but for clarity, only alternate steps are shown.



LEFT (OR RIGHT) CHANNEL	RIGHT (OR LEFT) CHANNEL	f_1 c/s
a	a'	720
b	b'	360
c	c'	180
d	d'	90
e	e'	45

Fig. 10 - Amplitude/frequency response curves of networks used to introduce interchannel amplitude differences at low frequencies. (Alternate steps shown). f_1 variable

4.2. Results

Figs. 11(a), 11(b) and 11(c) show the results of the tests in the listening room for organ, drum and double bass respectively. Curve (i) in each case shows the percentage of observations in which there was no perceptible image displacement, and curve (ii) the percentage of observations in which the edge of the image was less than 0·1 stage width from the centre. Even with the maximum interchannel difference between amplitude/frequency characteristics indicated in Fig. 10, the image rarely extended as far as 0·2 on the scale and the data was therefore insufficient to allow a reliable curve to be drawn for this condition. As in the corresponding curves in Fig. 6, the abscissae are plotted to a Gaussian probability scale, and the curves of best fit approximate to straight lines. It will be noted that whereas Fig. 6 covers three different bandwidths, Fig. 11 relates to three different musical instruments.

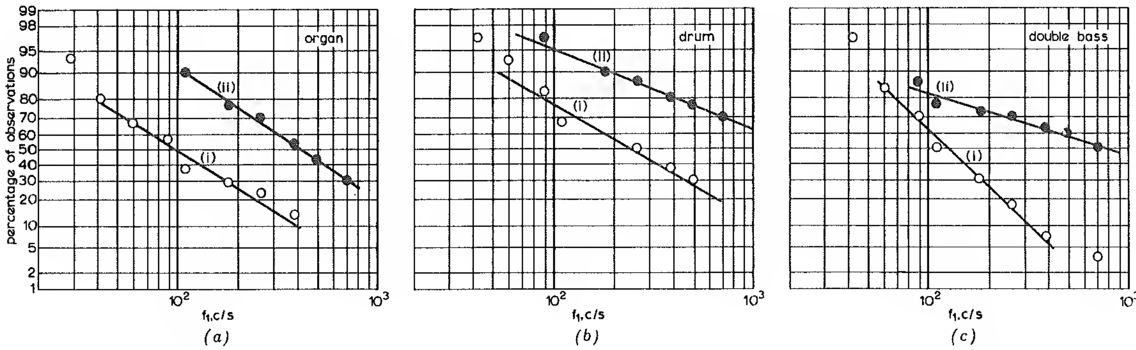


Fig. 11 - Subjective effect of difference between amplitude/frequency characteristics of left and right channels at low frequencies. Divergence of channels expressed in terms of f_1

Numbering of curves:-

(i) Percentage of observations in which there was no perceptible image displacement
(ii) Percentage of observations in which the edge of the image was less than 0·1 stage width from centre

Table 3, derived from Figs. 11(a), 11(b) and 11(c), shows the values of f_1 for which, in 50% or more of the observations, the effect of the interchannel amplitude difference can be classified as 'imperceptible', and 'edge of image off-centre by less than 0·1 of stage width' respectively. The standard error of the mean is given in each case to the nearest 0·05 octave.

TABLE 3

Tests in Listening Room

SUBJECTIVE IMPAIRMENT OF NOMINALLY CENTRAL IMAGE IN 50% OF OBSERVATIONS	ORGAN		DRUM		DOUBLE BASS	
	f_1 c/s	S.E. (octave)	f_1 c/s	S.E. (octave)	f_1 c/s	S.E. (octave)
Imperceptible	96	0·4	240	0·45	124	0·3
Edge of image off-centre by less than 0·1 stage width	406	0·4	1700	0·65	760	0·85

In the dead room, the values of f_1 obtained were nearly the same as those shown in Table 3 and are not therefore reproduced here. Such small differences as existed between the two sets of figures, though barely significant statistically, suggested that the effects of interchannel amplitude differences were, if anything, less noticeable in the dead room than in the listening room.

The supplementary experiment carried out to determine the width of an unimpaired central image yielded results which were in some cases significantly larger than those given in Section 3.2. The average image width in the listening room was 0·14, 0·13 and 0·09 of the stage width for the organ, drum and double bass respectively, the standard error being about 0·013 of the stage width in each case. In the dead room, the image width was slightly less for the drum and double bass, though for the organ, which has a greater middle frequency content, no significant difference was observed. In some later experiments with male speech (which contains no very low-frequency components) the image was found to be narrower in the listening room than in the dead room; it appears, therefore, that at low frequencies the effect of the acoustic environment on the width of a central image depends to some extent on the part of the spectrum involved.

As explained in Section 3.2, the distance by which the edge of the image was displaced in reaching a particular position on the numbered scale can be estimated by subtracting from the scale reading one half the width of the unimpaired central image.

Figs. 12 and 13, derived from Fig. 11 by interpolation, show the amplitude/frequency characteristics of the left- and right-hand channels for which, in 50% or

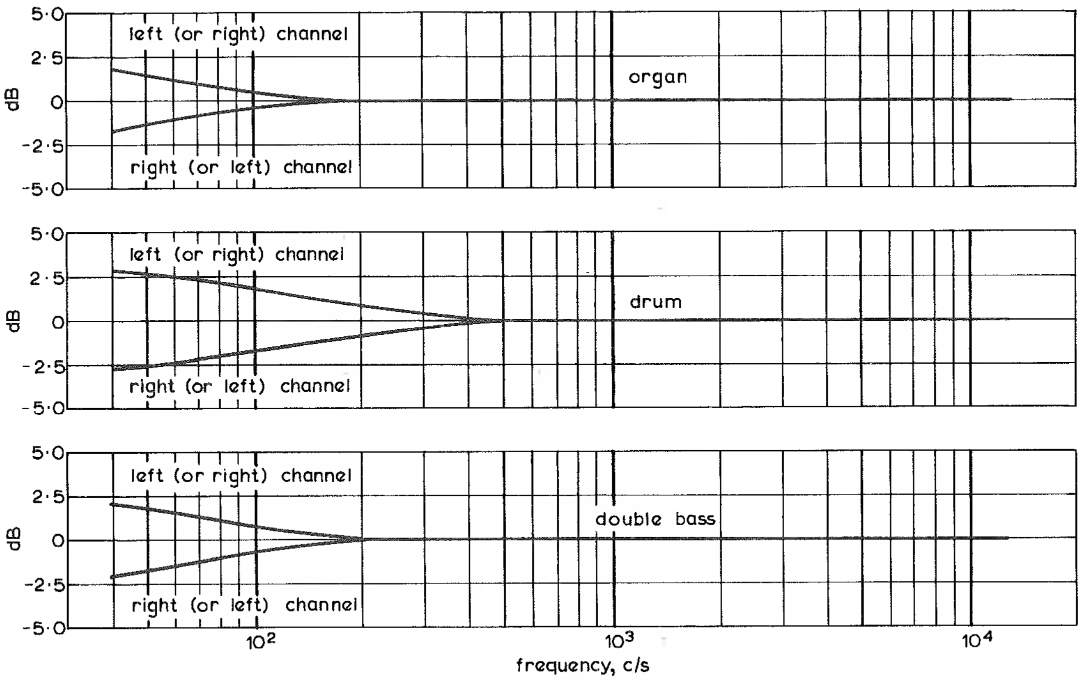


Fig. 12 - Amplitude/frequency characteristics of left and right channels at low frequencies for which there was no perceptible image displacement in 50% of observations

——— f_1 variable

more of the observations, the subjective impairment would be classified respectively as 'imperceptible' and 'edge of image off-centre by less than 0·1 of stage width'. It will be seen that for the same degree of image impairment, a much greater divergence between the channel characteristics could be permitted at low than at high frequencies.

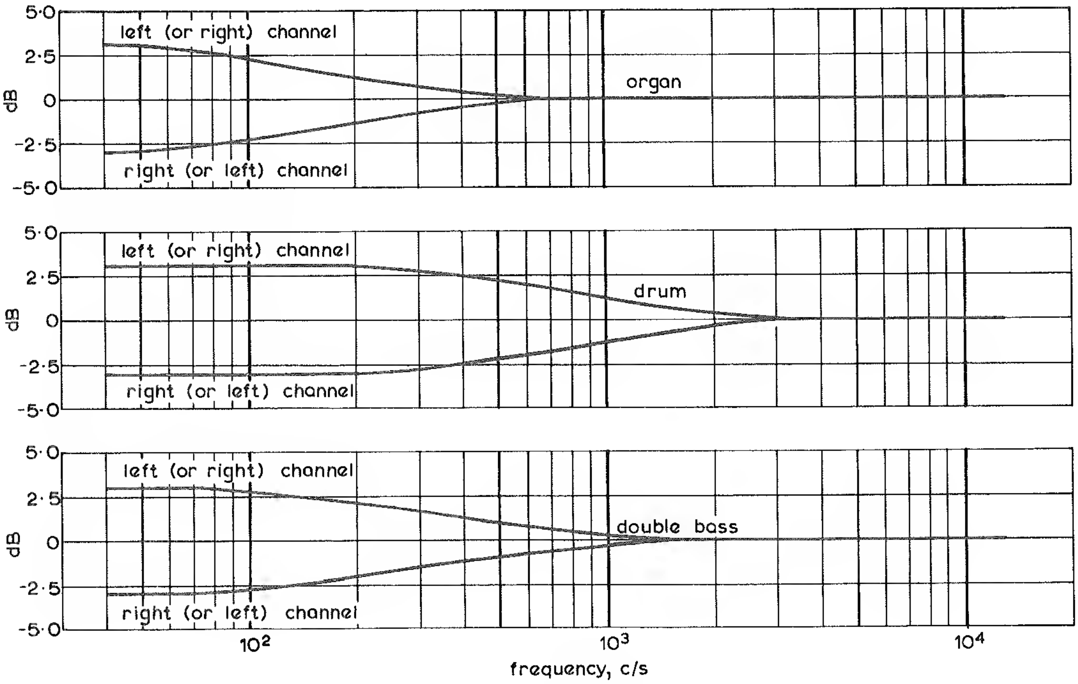


Fig. 13 - Amplitude/frequency characteristics of left and right channels at low frequencies for which the edge of the image was less than 0·1 stage width from centre in 50% of observations

——— f_1 variable

5. CONCLUSIONS

From the foregoing information it is now possible to consider the tolerances which might be imposed in practice on the matching of the amplitude/frequency characteristics of the left- and right-hand channels of a stereophonic system. To this end, it is convenient to replot the curves of Figs. 7, 8, 9, 12 and 13 to show, instead of the actual amplitude/frequency characteristics of the two channels, the difference between the two; the resulting data is presented in Figs. 14, 15 and 16 for the high-frequency range and in Figs. 17 and 18 for the low-frequency range.

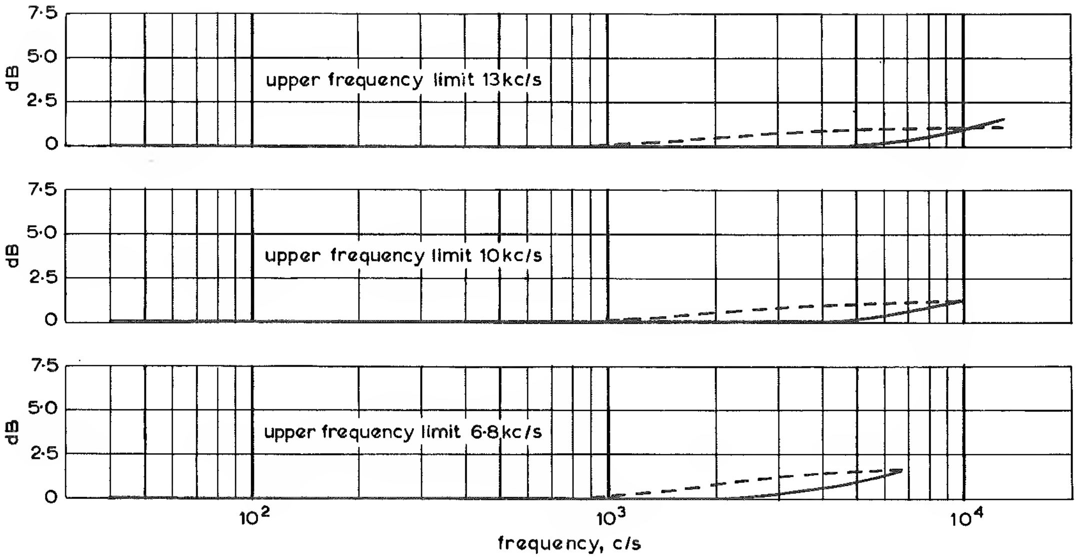


Fig. 14 - Difference between amplitude/frequency characteristics of left and right channels for which there was no perceptible image displacement in 50% of observations

Frequency characteristics of left and right channels diverging at high frequencies

——— f_1 variable ---- S variable

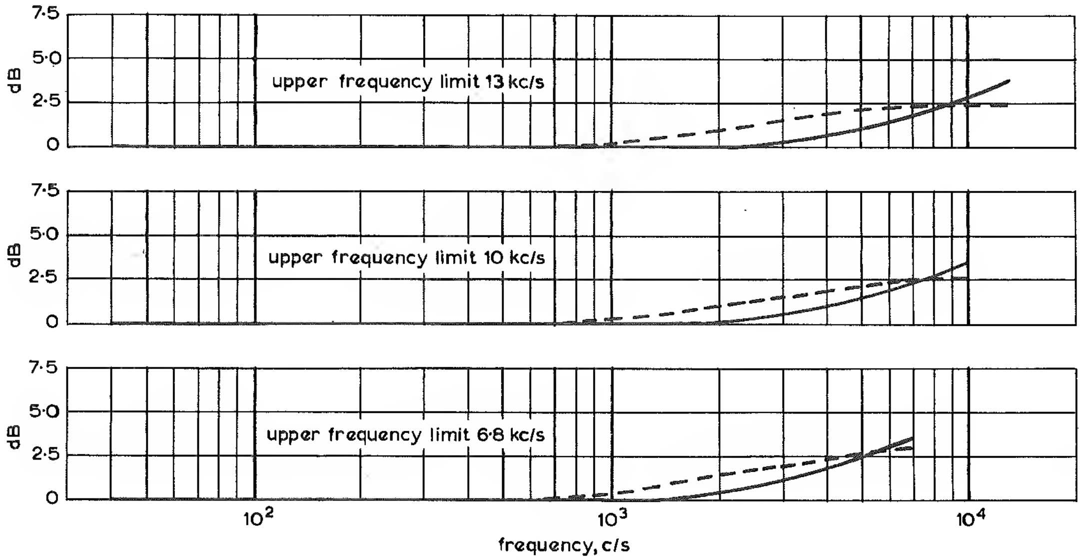


Fig. 15 - Difference between amplitude/frequency characteristics of left and right channels for which the edge of the image was less than 0·1 stage width from centre in 50% of observations

Frequency characteristics of left and right channels diverging at high frequencues

——— f_1 variable ---- S variable

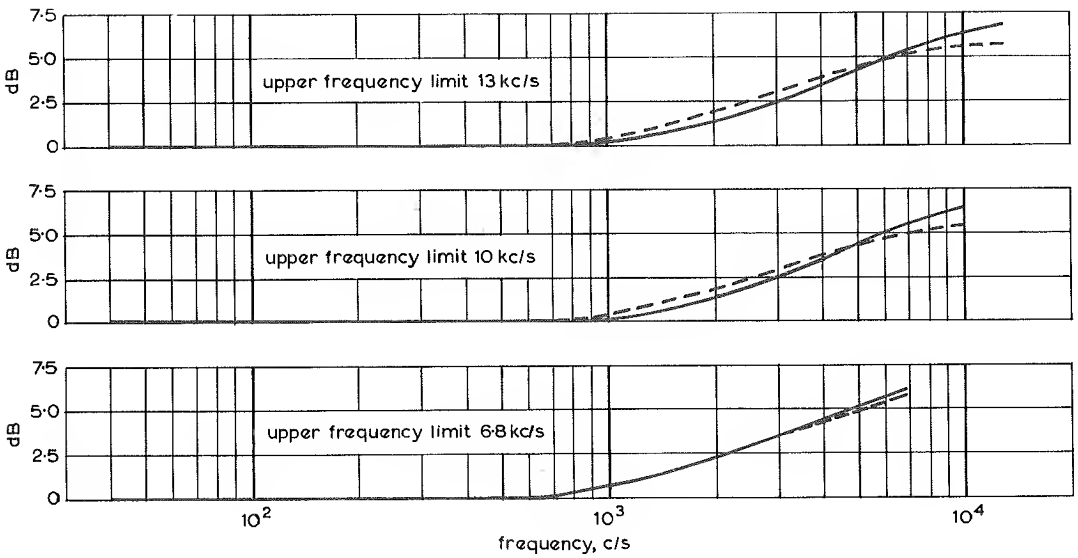


Fig. 16 - Difference between amplitude-frequency characteristics of left and right channels for which the edge of the image was less than 0·2 stage width from centre in 50% of observations

Frequency characteristics of left and right channels diverging at high frequencies

——— f_1 variable – – – – S variable

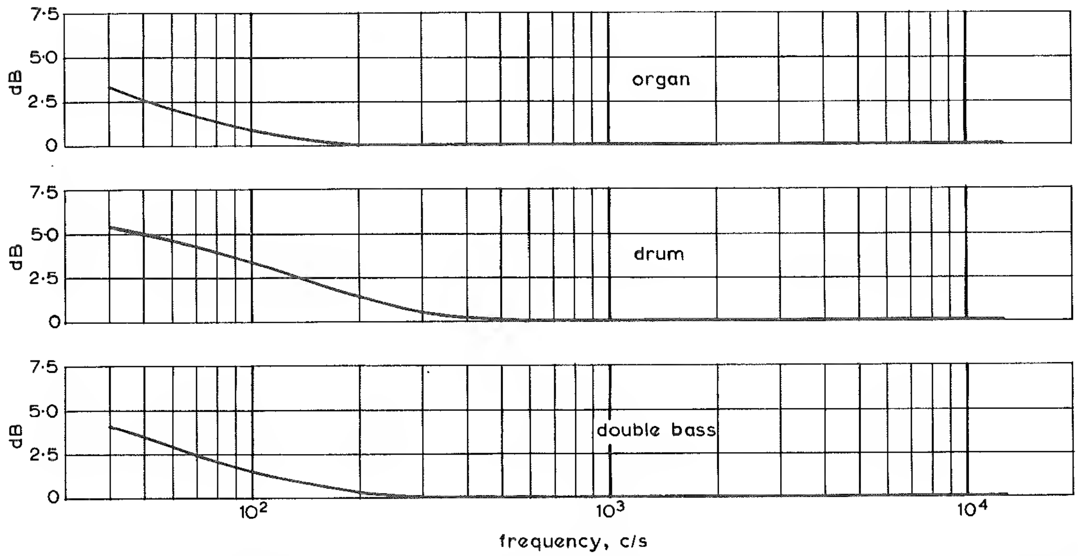


Fig. 17 - Difference between amplitude/frequency characteristics of left and right channels for which there was no perceptible image displacement in 50% of observations

Frequency characteristics of left and right channels diverging at low frequencies

——— f_1 variable

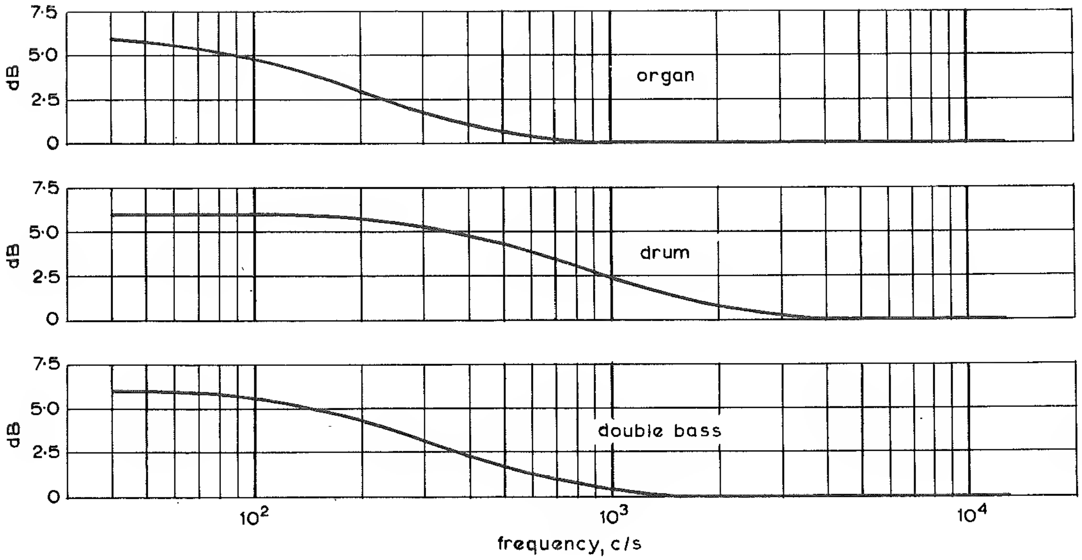


Fig. 18 - Difference between amplitude/frequency characteristics of left and right channels for which the edge of the image was less than 0·1 stage width from centre in 50% of observations

Frequency characteristics of left and right channels diverging at low frequencies

——— f_1 variable

In drawing conclusions from this data, the following points should be specially noted:

(a) The experiments were confined to the case in which the amplitude/frequency characteristics of the left- and right-hand channels depart from uniformity by equal and opposite amounts. In applying the results to the more general case, it is tacitly assumed that dispersion of the stereophonic image is unaffected by changes in amplitude/frequency characteristic applying to both channels equally.

(b) The curves in Figs. 14 to 18 represent a circuit condition for which the effects described were observed on programme material covering a range of frequencies; they do not represent the effect of differences in the gain or loss of the left- and right-hand channels at any one frequency considered separately.

(c) Interchannel amplitude differences may be of opposite sign at the two ends of the audio-frequency band. A nominally central image having components at both extremes of the band could then be dispersed both to left and to right, the overall width being determined by the sum of the two effects.

As a basis for discussion, it seems reasonable to consider two degrees of tolerance, the first based on the most critical case and the second representing a practical compromise when the more stringent requirements cannot be met. The

former limit could be derived from the data for imperceptible impairment in 50% of cases; the latter could appropriately be arrived at by assuming the edge of a nominally central image to be, in 50% of cases, off-centre by less than 0·1 of a stage width. In Fig. 19 an attempt has been made to draw up a set of tolerances on these lines. It is assumed that the gain or loss of the left- and right-hand channels is made equal at 800 c/s; an arbitrary tolerance of 0·5 dB has been allowed in the mid-band region. Curve (a) represents the limit of perceptibility, below which it is unnecessary to go, curve (b) the higher limit, representing a detectable but small degree of impairment. The dotted line (c) shows for comparison the possible differences in amplitude/frequency characteristic between two lines conforming to the C.C.I.T.T. limits (1960) for normal Type A programme circuits.

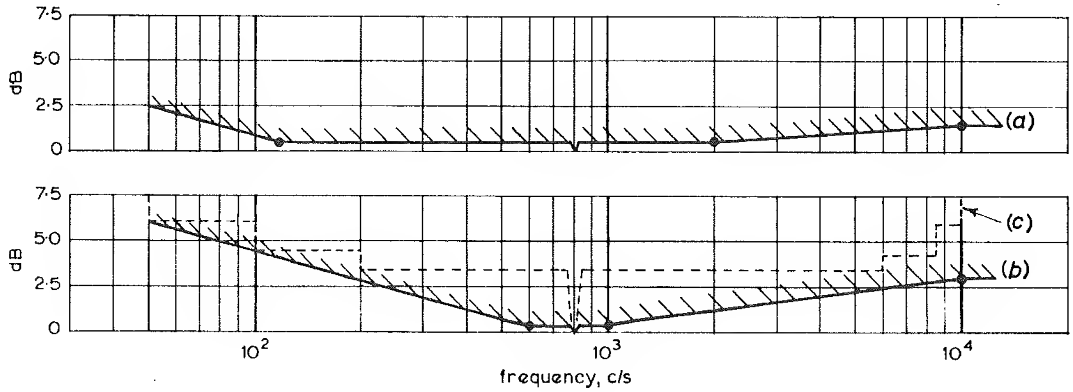


Fig. 19

(a), (b) Suggested tolerances for difference between frequency characteristics of left and right channels taking gain or loss of 800 c/s as zero

(a) Limit of perceptibility (b) Acceptable limit if necessary

(c) Overall limit of variation in frequency characteristic permitted by C.C.I.T.T. tolerances of normal Type A programme circuits

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